

# RECLAMATION

*Managing Water in the West*

## **San Ildefonso Pueblo River Maintenance Priority Site**

### **Geomorphic Trends Assessment Final Report**



**Department of the Interior  
Bureau of Reclamation  
Albuquerque Area Office**

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Bureau of Reclamation  
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The mission of the Department of the Interior is to protect and provide access to our Nation's natural and cultural heritage and honor our trust responsibilities to Indian tribes and our commitments to island communities.

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# Introduction

At the San Ildefonso Pueblo River Maintenance Priority Site, the Rio Grande is eroding the east bank, migrating towards the Pueblo's fishing pond (Figure 1). At present, a berm/road separates the river from the pond which is also in jeopardy of river erosion. The fishing pond is located approximately 1.5 miles upstream from where New Mexico Highway 502 crosses the Rio Grande (Figure 1); the USGS Rio Grande gage at Otowi is located immediately downstream of the 502 HWY bridge. Upstream of the fishing pond about 1 mile, the Pojoaque River joins the Rio Grande, while Contrayerba Canyon arroyo joins the Rio Grande from the west, across from the fishing pond at approximately River Mile 259.

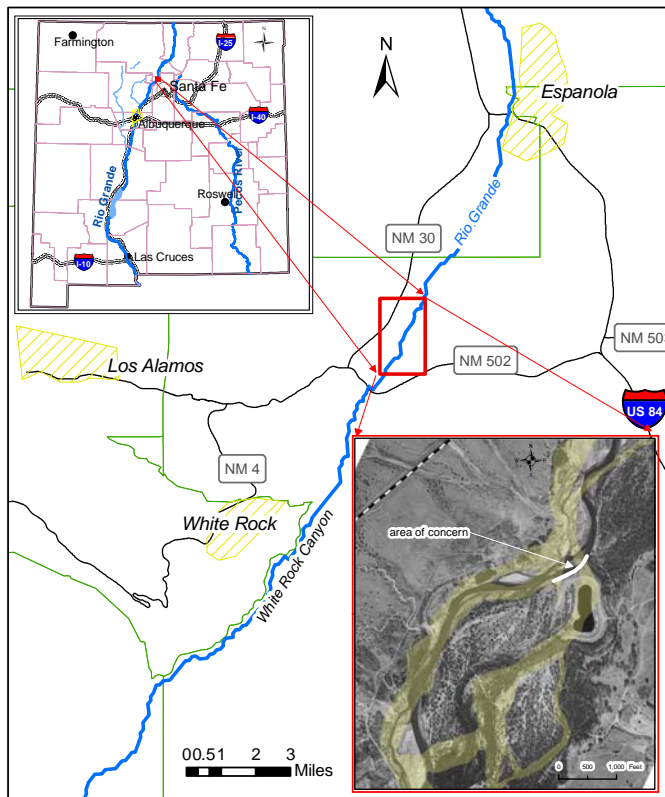


Figure 1: Location map of the San Ildefonso Pueblo River Maintenance priority site. The inset 2001 aerial photo in the lower right corner contains an overlay of the 1935 active channel position (transparent yellow).

The main goal of this study is to determine when channel migration might endanger the San Ildefonso fishing pond, as the current channel appears to be migrating towards the pond. The objectives of the study are to evaluate relevant geomorphic parameters which influence and/or describe the condition of the Rio Grande and estimate future conditions of the river especially focusing on the river bend migrating towards the fishing pond.

# Historical Information

Historical data for this reach consists primarily of channel outlines (planforms) created from archived aerial photography that are available in digital format. With the exception of the 2001 data, all the planform data used in Figure 2 were created by Jan Oliver in Reclamation's Remote Sensing Group in the Technical Services Center, Denver, CO. The planforms created by Oliver were digitized from geo-referenced historical aerial photography (1935, 1972, 1979, 1987 and 1992). The 2001 channel planform data were drawn in ArcMap 9.0 (GIS) using Reclamation's 2001 digital aerial photography by T. Massong. Historical channel and island widths were measured at twenty locations, approximately 200 meters apart then averaged to create single width values for each year of data available (Table 1). For three of the digitized channel planform data, 1935, 1972 and 1987 (Figure 2), the Contrayerba Canyon Arroyo was not mapped by J. Oliver; the exact reason for the omission is unknown.

Historical photo data shows that this section of the Rio Grande evolved from a very large island braided channel with very narrow sections between the braids (Figure 2). The earliest photo data from 1935 shows that the Rio Grande was a relatively dynamic river with a variety of features: active channel, active bars, vegetated islands (a.k.a., inactive bars), historical surfaces and active floodplain. The vegetated bars filled approximately 40% of the total width of the 'channel-corridor' (Table 1). The current fishing pond is located within a 1935 side channel.

Table 1: Active channel width for the Rio Grande (1935-2001).

	<b>1935</b>	<b>1972</b>	<b>1979</b>	<b>1987</b>	<b>1992</b>	<b>2001</b>
total width (m)	359	140	141	146	134	130
wetted width (m)	217	140	130	143	128	119
% veg bars	39	0	8	2	5	8

By 1956, the 1935 side channel appears to have become the main Rio Grande channel (Figure 3). However, a channel re-alignment project in this reach moved the main channel west, back to the approximate location of the main channel in 1935. In this re-alignment project, several small bends were also abandoned; the created channel in the 1956 project was much less wide than the old channel and was much straighter. Although no documentation are available, we assume that the fishing pond was built shortly after this project was completed; we also assume that the Kellner Jetty Jacks that are present in the reach (Figure 4) were also emplaced during this channel floodway construction. Based on field observations, several of the jack lines appear to have been placed parallel to the approximate location of the 1956 pilot channel. Some of the jetty jacks have subsequently 'fallen' into the Rio Grande (Figure 4).

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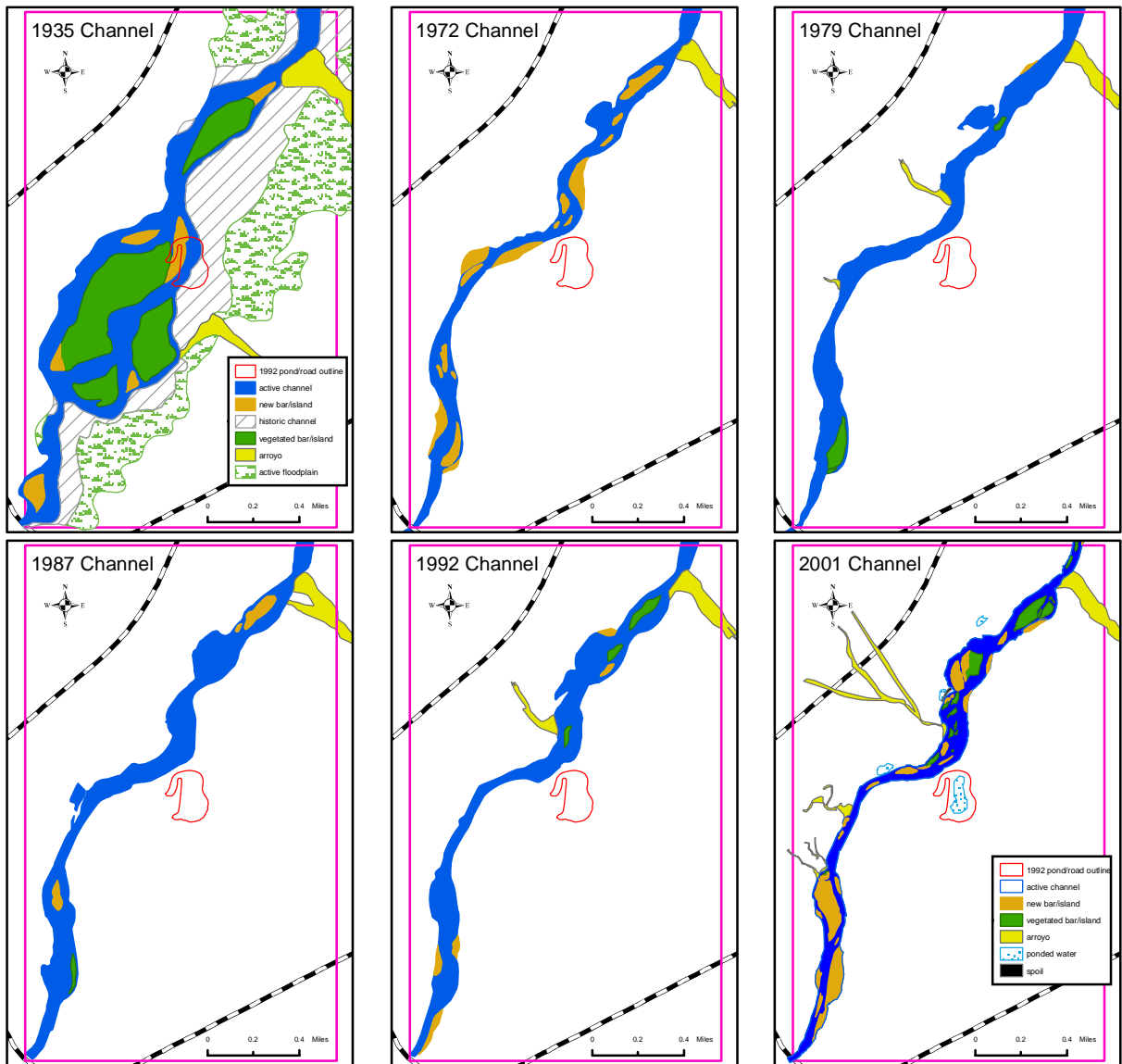


Figure 2: Channel locations for the area surrounding the San Ildefonso fishing pond priority study site for 1935, 1972, 1979, 1987, 1992, 2001; 1992 position of the fishing pond is outlined in red for each of the years.

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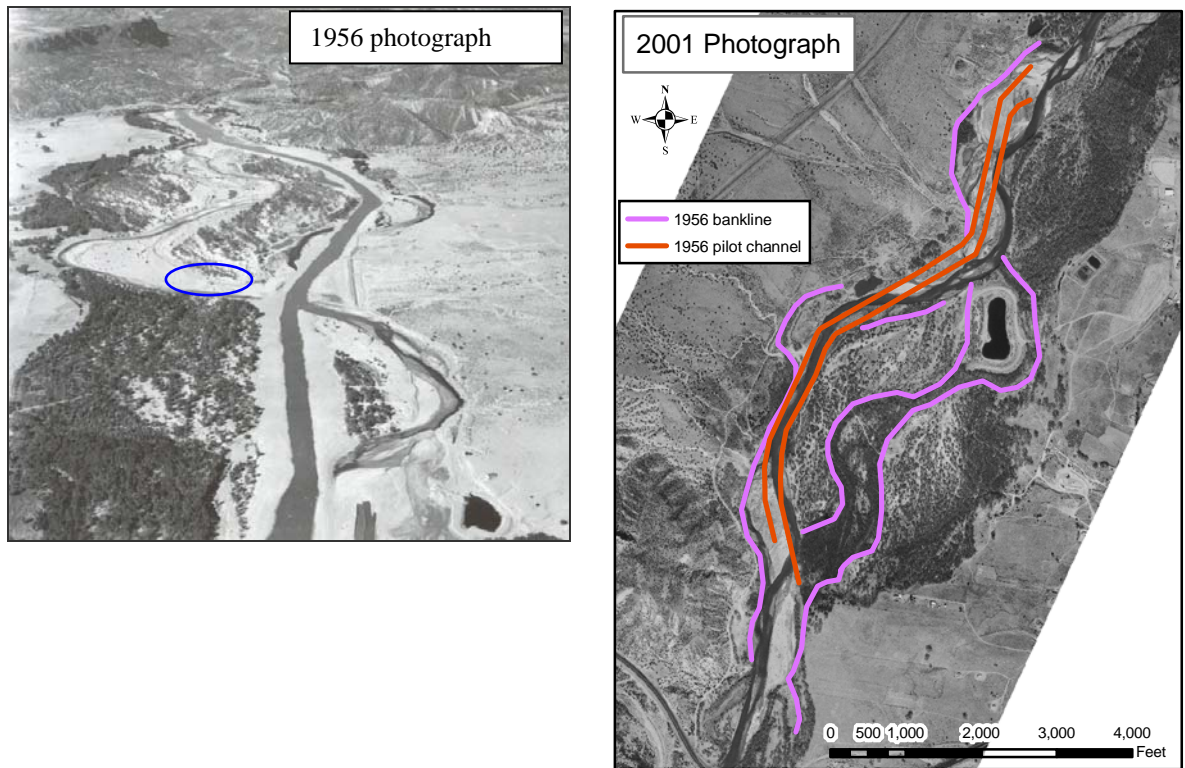


Figure 3: The 1956 photograph (left) shows the channel re-alignment of the Rio Grande (looking downstream) on the Pueblo of San Ildefonso (Bureau of Reclamation photo archives); blue oval designates the approximate location of the fishing pond. The right figure shows an approximate graphical view of the re-alignment overlain on the 2001 aerial photographs (right).



Figure 4: Jetty line that has 'fallen' into the Rio Grande at the Pueblo of San Ildefonso.

By 1972, the 1956 pilot channel had widened some, but the general channel location was the same, and no vegetated bars are present. Although several active bars were present by 1979, few of these vegetated. By 1987, channel width was increasing with few bars present (Figure 2).



By 1992, several bars, both vegetated and un-vegetated formed in the upstream part of the reach. At the mouth of Contrayerba Canyon arroyo, several of the new bars appear to be excavated spoils from the arroyo channel. The piles of sediment (Figure 5) are 15-25 feet tall and appear to partially deflect flow in the Rio Grande channel towards the east bank.



Figure 5: Spoil pile at the confluence of the Contrayerba Canyon arroyo and the Rio Grande. The flowing water is a Rio Grande side channel to the west of the main channel.

Between 1992 and 2001, the channel gained some sinuosity such that the bend immediately upstream from the fishing pond appears to be migrating towards the pond. The growth of numerous bars and some vegetated islands appears to be at least partially responsible for a reduced wetted channel width. The channel character in the 2001 planform data appears to be back to a bar/island braided form, similar to the form found in 1935. However, unlike the 1935 channel, the 2001 braids are relatively small and an extensive floodplain area is not present.

## **Geology**

The San Ildefonso Fishing Pond Priority Site lies on Quaternary alluvium deposited by the Rio Grande and its nearby tributaries (Figure 6, Anderson et al. 1997). The study site is located within the Espanola Basin, a well documented graben within the Rio Grande Rift zone. This basin is geologically controlled and centered at the Rio Chama/Rio Grande confluence (Kelley 1978), which is upstream from the study site. As with other Rio Grande grabens, the valley is filled primarily of fluvial and arroyo derived sediments including sand and gravel (Anderson et al. 1997; and Kelley 1978). Although the basin was likely intermittently blocked by large landslides located immediately downstream in White Rock Canyon, the Rio Grande currently drains the basin through White Rock Canyon; the canyon is approximately 1,000 feet deep and predominantly filled with the large Pleistocene age landslide deposits and to a lesser degree, fluvial sediments (Dethier 1997).

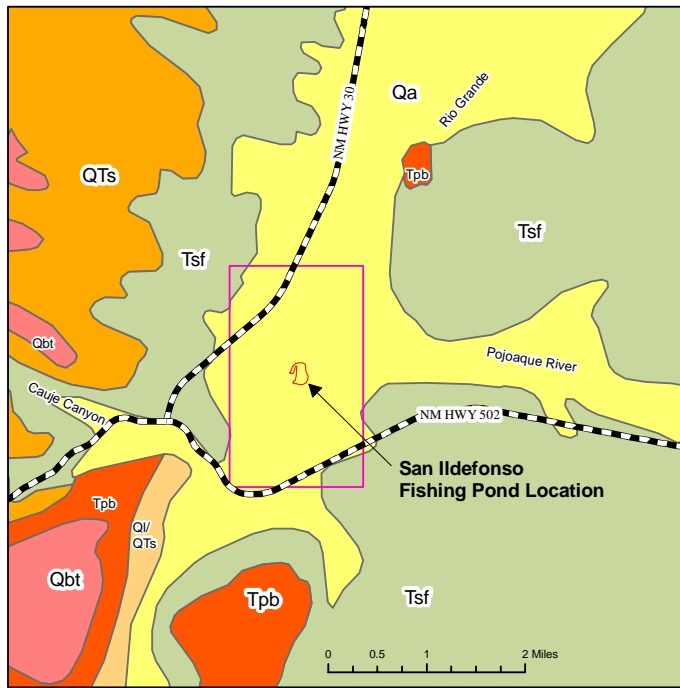


Figure 6: Close-up of the area surrounding the San Ildefonso fishing pond from the New Mexico Geologic Map (Anderson et al. 1997). **Qa** - Alluvium; upper and middle Quaternary. **QI/QTS** - Landslide deposits and colluvium within the Upper Santa Fe Group. **QTs** - Upper Santa Fe Group; middle Pleistocene to uppermost Miocene. **Qbt** - Bandelier Tuff. **Tpb** - Basalt and andesite flows; Pliocene. **TsF** - Lower and Middle Santa Fe Group; Miocene and uppermost Oligocene.

## Discharge and Sediment Supply

Less than 2 miles downstream from the study site is the USGS Rio Grande gage at the Otowi Bridge (Otowi gage) which provides discharge data (1895-present) and suspended sediment data collected since 1955. Peak flow data (Figure 7) show that the last large flows (>15,000 cfs) were in the early 1940s, with the highest peak recorded in 1920 at 24,400 cfs. These data also show that after 1942 the magnitude of the peak flows passing the Otowi gage are significantly smaller than prior to 1942. In fact, a simple recurrence analysis of the peak flow data shows that the 2-yr event prior to 1942 (1895-1942) was 10,400 cfs, but after 1942 is only 5,800 cfs (Table 2), almost a 50% reduction in discharge.

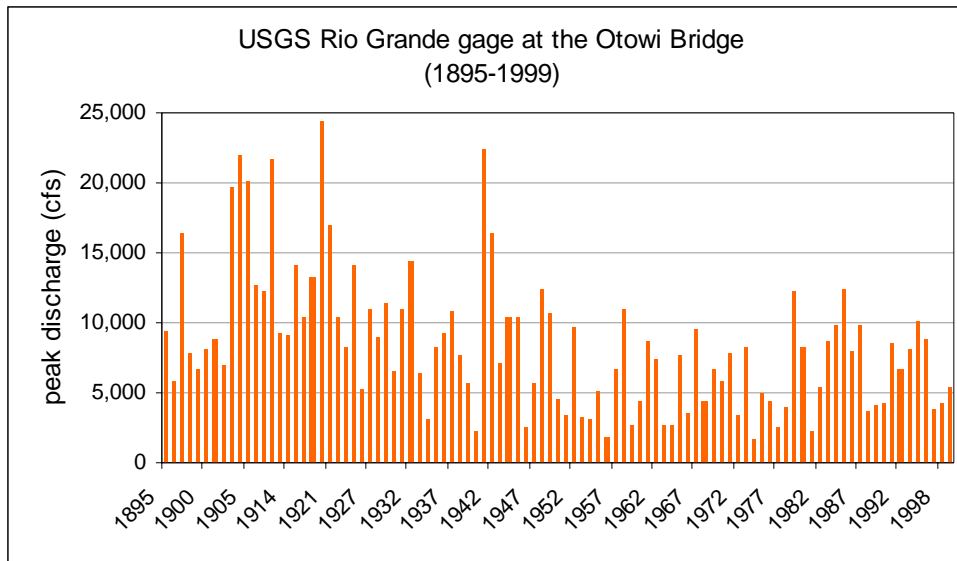


Figure 7: Peak flow data for the USGS Rio Grande gage at the Otowi Bridge, NM (Hydrosphere, 2000).

Table 2: Summary of 2-yr, 5-yr, and 10-yr return flows (cfs) for the USGS Rio Grande gage at Otowi Bridge, NM. A simple recurrence interval ranking method was used: recurrence interval=(n+1)/rank; where n is the number of years of record and rank is the relative rank of each flow within the period of record, such that the largest flow ranks #1.

	2 yr Return Flow	5 yr Return Flow	10 yr Return Flow
Entire Record (1895-1999)	8,200	11,500	15,000
1895-1942	10,400	16,400	21,700
1943-1999	5,800	9,700	10,400

The 'cause' for this reduction in peak flows can be attributed to two main processes: climate change (a severe drought in the 1950s) and flood water storage in El Vado and Abiquiu Reservoirs on the Rio Chama. A well documented drought occurred in the 1950s throughout the state of New Mexico (Scurlock 1998). A drought pattern is present in the Otowi gage data during the 1950s and into the 1960s as few spring runoff peaks surpass the 2-year event level (Figure 7). Just prior to and during the drought event, two dams were built on the Rio Chama, a major tributary to the Rio Grande which joins just upstream of the study site: El Vado dam (1934/5) and Abiquiu dam (1963). El Vado and Abiquiu dams were built primarily for flood control by Reclamation and the Army Corps of Engineers. As seen in the 2005 spring runoff, spring peak flows can be dramatically reduced through a combined storage at these dams/reservoirs (Figure 8). If flood water storage had not occurred in 2005 on the Rio Chama, the runoff would have peaked at over 11,000 cfs on the Rio Chama at Chamita and 14,000 cfs on the Rio Grande at Otowi Bridge. This size event at Otowi Bridge is estimated to have a return period of less than 5 years for the 1895-1942 period, but greater than a 10-year event for the 1943-1999 period. Although the 1950s drought is the likely main 'cause' for the reduced peak flows in the 1950s, flood operations on the Rio Chama (a.k.a., reservoir storage of peak flows) is the likely 'cause' of a continuation of the reduced peak flows after the drought ended in the 1960s. Consequently, the peak flow record after 1942 will be used to estimate channel conditions and extrapolate physical trends into the future for this study.

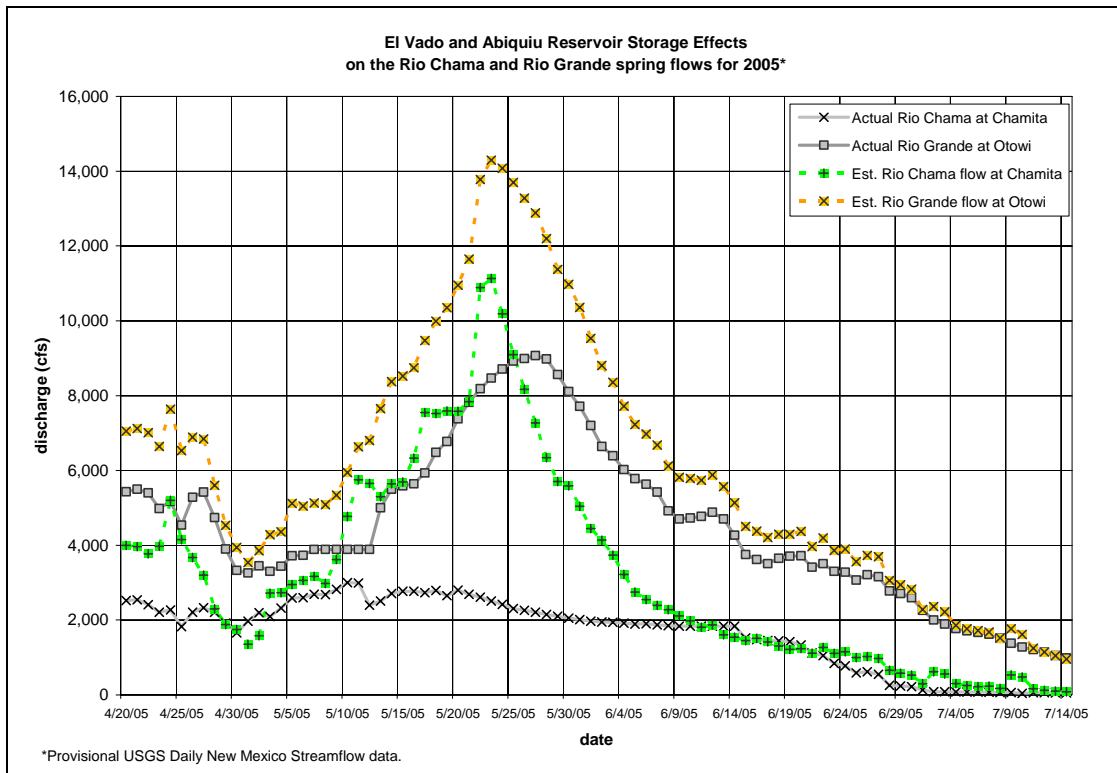


Figure 8: An illustration of the effects of flood storage at El Vado and Abiquiu Reservoirs on the Rio Chama and Rio Grande hydrographs (daily flow values). The estimated Rio Chama flow at Chamita is a rough estimate of the peak runoff in 2005 if reservoirs had not stored water during the runoff event; the estimate adds together the discharge that was released during runoff (actual Rio Chama at Chamita flow) and the discharge that was stored in El Vado and Abiquiu Reservoirs. The estimated Rio Grande flow at Otowi combines the estimated Rio Chama flow at Chamita with measured Rio Grande flows.

The suspended sediment data collected at the Otowi gage shows that concentration of suspended sediment also changed, however the change was a reduction in concentration between 1974-1990, with a return to previous levels after 1990. Between 1974 and 1990 the amount of suspended sediment measured at the Otowi gage decreased to less than half of the historic levels (Figure 9 and Table 3). Since 1990, the data show that sediment concentrations have increased to historical levels. Although the Abiquiu dam on the Rio Chama obviously influence peak flows, these operations which began in 1963 do not appear to be substantially influencing the suspended sediment concentration.

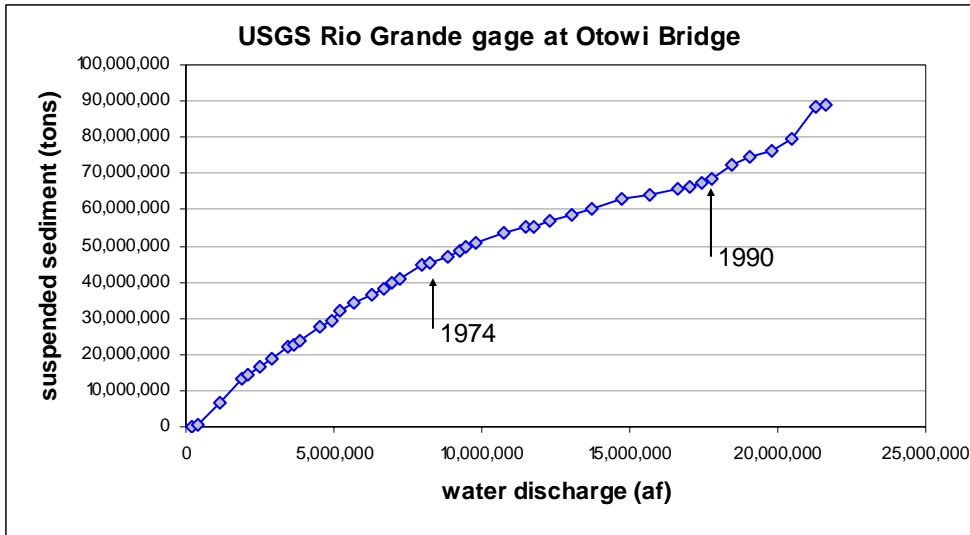


Figure 9: Cumulative suspended sediment data compared to water discharge for the USGS Rio Grande gage at the Otowi Bridge, NM (Hydrosphere, 2000).

Table 3: Suspended sediment concentrations for the USGS Rio Grande gage at Otowi Bridge (1955-1996).

Period	concentration (mg/l)
1955-1974	4,545
1974-1990	1,870
1990-1996	4,220



## Current Channel Characteristics

The current channel dimensions were estimated using cross section data collected in February 2005 (Figure 10). These data were modeled in the U.S. Army Corps of Engineering HEC-RAS (2004) for both the 2-year return flow (5,800 cfs) and the 5-year return flow (9,700 cfs). The HEC-RAS model was calibrated for water surface elevations in February when the data were collected, and then again for observed water's edge data collected in May 2005 at a discharge of approximately 6,200 cfs. During both calibrations, the Manning's 'n' value was 0.028.

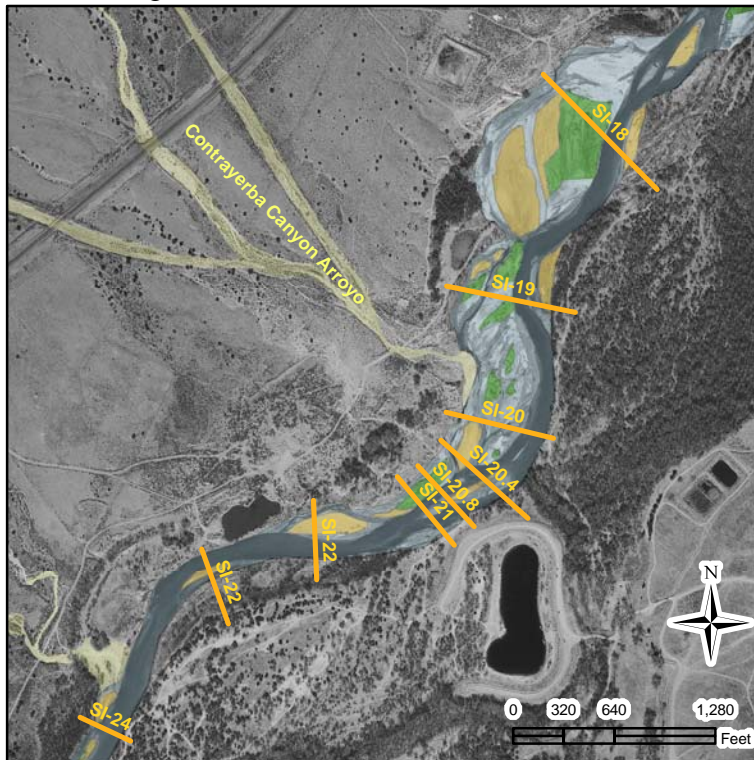


Figure 10: Reclamation cross section locations on the Rio Grande on the Pueblo of San Ildefonso.

The results show that the channel width remains similar between the two different flows, except at SI-18 where the extra 3,900 cfs discharge increases the channel width from 700 feet to 925 feet (Table 4) as the vegetation island becomes inundated (acting as a floodplain). For the remaining cross sections, no floodplain surfaces exist for these flow levels. Interestingly the depth only increases about a foot between the 2-yr event and the 5-yr event for both the maximum and average flow depths. The velocity also increases by about 1 ft/sec. Based on these results, channel parameters change by less than 20% between a 2-yr and a 5-yr event indicating that in-channel characteristics are relatively insensitive to increased flows up to the 5-yr event.

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Table 4: Summary of current channel dimensions in the Rio Grande at the San Ildefonso Pueblo River Maintenance Priority Site for both the 2-yr (5,800 cfs) and 5-yr (9,700 cfs) return flows.

5,800 cfs	Width (ft)	Max. Depth (ft)	Ave. Depth (ft)	Flow Area (sq. ft)	Velocity (ft/sec)	Wetted Perimeter (ft)	Water Surface Elevation (ft)
SI-18	300	8.4	3.4	1030	5.7	300	5515.79
SI-19	450	6.1	2.7	1200	4.9	450	5513.69
SI-20	540	7.3	2.5	1360	4.4	540	5512.11
SI-20.4	570	6.5	2.8	1570	3.8	580	5511.37
SI-20.8	330	6.8	3.5	1130	5.4	330	5510.88
SI-21	430	6.8	2.9	1230	5.2	430	5510.56
SI-22	330	7.3	3.2	1070	5.6	330	5509.55
SI-23	230	7.6	3.9	900	7.0	230	5508.42
SI-24	260	7.5	3.7	970	6.2	260	5506.76
Average Value	360	7.3	3.2	1110	5.6	370	--

9,700 cfs	Width (ft)	Max. Depth (ft)	Ave. Depth (ft)	Flow Area (sq. ft)	Velocity (ft/sec)	Wetted Perimeter (ft)	Water Surface Elevation (ft)
SI-18	920	9.5	2.7	2480	6.4	920	5516.87
SI-19	610	7.1	3.2	1960	5.7	610	5514.71
SI-20	590	8.6	3.6	2110	4.8	600	5513.40
SI-20.4	600	8.1	4.2	2530	4.0	600	5512.99
SI-20.8	450	8.3	4.2	1890	6.2	450	5512.43
SI-21	450	8.4	4.3	1930	6.2	460	5512.13
SI-22	430	9.0	4.1	1750	6.1	440	5511.26
SI-23	490	9.2	3.4	1660	8.5	490	5509.99
SI-24	280	8.5	4.5	1260	8.1	280	5507.84
Average Value	540	8.6	3.7	1880	6.5	540	--

## Bed Material

Bed material has been collected since 1994 in this reach. Sediment samples collected between 1994 and 1998 were grab samples, typically with a shovel and bag. For grain size estimates, these sediment samples were dry sieved and binned according to sieve sizes. The 2005 data represent the armour layer, as the data were collected via the Wolman pebble count method, hence only the sediment surface was assessed. Regardless of method, the data show that the grain size has consistently been either very coarse gravel (32-64 mm) or cobbles (>64 mm) throughout the 1990s and up to 2005 (Table 5). Although the data are not complete, the median ( $d_{50}$ ) grain size data shows that a decrease in grain size may have occurred in this reach throughout the 1990s. This apparent decrease in sediment size is consistent with the increase in suspended sediment measured at the USGS Rio Grande gage at Otowi, as increased sediment supply is often associated with a reduction in the size of sediment found on the channel bed. However, more data is required to confirm this trend.

Table 5: Comparison of the current and historical bed material data collected in the Rio Grande in the San Ildefonso Pueblo study area. Grain size is in millimeters (mm).

	$d_{84}$					$d_{50}$			
	1994	1995	1998	2005		1994	1995	1998	2005
SI-18	79	125	--	98		63	67	--	45
SI-19				68					34
SI-20				56					32
SI-20.4				103					64
SI-20.8				90					50
SI-21	76	74	70	60		51	39	23	28
SI-22				75					43
SI-23				69					43
SI-24	76	78	36	95		49	59	16	38

## Bed Stability Assessment

Bed particles in an non-cohesive sediment theoretically become mobile once the shear on the channel bed reaches some threshold level known as the critical shear stress (Sturm 2001); by comparing current shear stress on the channel bed (basal shear stress or tractive force) to the critical shear stress, potential particle mobility can be estimated. Current bed material data consists of surface grain size information collected in February 2005 along with the corresponding cross section data. Critical shear stress estimates were calculated based on methods presented by Sturm (2001), while the tractive force was calculated using three methods: Brown (1986), Anderson et al. (1970), and HEC-RAS (2004). The results from these assessments were used to estimate the stability of the current bed sediments and to estimate the potential for bed scour (incision).

### Methods

#### *Critical Shear Stress*

For gravel bedded channels, the critical shear stress can be derived from the Shields parameter equation (Sturm 2001; Julien 1995) as the Shields parameter ranges from 0.039 to 0.052, with a well accepted average value of 0.045, which is used in this analysis:

$$\tau_{*c} = \tau_c / [(\gamma_s - \gamma) * d],$$

where  $\tau_c$  = Shields parameter,  $\tau_c$  = critical shear stress (lbf/ft<sup>2</sup>),  $\gamma$  = specific weight of water (62.4 lbf/ft<sup>2</sup>),  $d$  = particle diameter (ft), and  $\gamma_s$  = specific weight of the particle (assuming gravel is mostly composed of quartz  $\gamma_s \sim 165$  lbs/ft<sup>3</sup>, Lindeburg [2001])

#### ***Tractive Force/Basal Shear Stress***

The tractive force ( $\tau_o$ ) was estimated using three methods: Brown (1986), Anderson et al. (1970), and HEC-RAS (2004). The maximum value calculated from these three methods was used to assess potential bed mobility.

The tractive force method as defined by Brown (1986):

$$\tau_o = k_j * \gamma * R * S,$$

where  $\tau_o$  = tractive force (lbf/ft<sup>2</sup>),  $k_j$  = a coefficient (usually assumed to be 1),  $\gamma$  = specific weight of water (62.4 lbf/ft<sup>2</sup>),  $R$  = hydraulic radius (ft), and  $S$  = the energy grade line (or channel) slope.

The tractive force method as defined by Anderson, Paintal, and Davenport (1970) is a variation of the Brown method which uses  $k_j=1.5$  rather than  $k_j=1.0$ :

$$(\tau_o)_{\max} = 1.5 * \gamma * R * S,$$

where  $(\tau_o)_{\max}$  = maximum bed shear stress (lbf/ft<sup>2</sup>),  $R$  = hydraulic radius (ft),  $S$  = the energy grade line slope, and  $\gamma$  = specific weight of water (62.4 lbf/ft<sup>3</sup>).

The HEC-RAS (HEC-RAS Hydraulic Reference Manual 2004) shear stress calculations are also based on the tractive force method and can be written as follows:

$$\tau = \gamma * R_{\text{avg}} * S_f,$$

where  $\tau$  = shear stress,  $\gamma$  = specific weight of water (62.4 lbf/ft<sup>2</sup>),  $R_{\text{avg}}$  = Average hydraulic radius for a given reach, and  $S_f$  = slope of the energy grade line (friction slope) for a given reach.

#### ***Stable Grain Size***

Once the shear stress and the critical shear stress are known, the values can be compared to estimate the mobility of the bed particles. Generally if the basal shear stress (the force exerted by the water) is greater than the critical shear stress (submerged weight of particle keeping it immobile) then the particle will become mobile. Rearranging the Shields parameter equation, the stable grain size can be estimated. In this assessment the estimated stable grain size was compared to the current  $d_{50}$  and  $d_{84}$  grain sizes from the 2005 data set.

#### ***Channel Bed Stability***

The channel bed stability was determined by evaluating the stability of the surficial sediment bed material data that was collected with the Wolman pebble count method. No incision is predicted when the estimated stable grain diameter is smaller than the current  $d_{50}$  grain size. Significant incision is predicted when the estimated stable grain size is greater than the current  $d_{50}$  grain size. When the estimated grain size is between the current  $d_{50}$  and  $d_{84}$ , then a minor amount of incision is possible.

## Results

The larger grain sizes ( $d_{84}$ ) appear to be stable at each cross section up to the 5-yr return flow (~10,000 cfs) based on the shear stress modeling results; however, at several cross sections, the  $d_{50}$  is mobile at these same flows indicating that the channel is responsive to the average flow events. Except at two cross sections, all of the  $d_{50}$  grain sizes become mobile below an estimated 5-year event (Table 6). In fact, with the exception of the two immobile cross sections, the  $d_{50}$  grain sizes become mobile at flows just greater than the 2-yr event. The two cross sections that have estimated immobile  $d_{50}$  grain sizes (Table 6), have the largest  $d_{50}$  grain sizes within the study reach, but also, both of these cross sections are located just downstream from arroyo tributary confluences (Figure 10). Based on these sediment mobility results, only minor amounts of bed scour/incision are estimated throughout the reach at the average flow (Table 7). Of the 9 cross sections, 3 cross sections are not likely to have any incision as the  $d_{50}$  is greater than the estimated stable grain size.

Table 6: Results of the tractive force-critical shear stress comparisons that estimate potential bed mobility for the  $d_{50}$  at each cross section at San Ildefonso Pueblo.

	Grain Size (mm)	2000 cfs	3000 cfs	4000 cfs	5000 cfs	5800 cfs	7000 cfs	9700 cfs	10,000 cfs
SI-18	61	no	no	no	no	no	no	no	no
SI-19	34	no	no	no	no	no	yes	yes	yes
SI-20	32	no	no	no	no	yes	yes	yes	yes
SI-20.4	64	no	no	no	no	no	no	no	no
SI-20.8	50	no	no	no	no	no	yes	yes	yes
SI-21	36	no	no	yes	yes	yes	yes	yes	yes
SI-22	43	no	no	no	no	no	yes	yes	yes
SI-23	43	no	no	yes	yes	yes	yes	yes	yes
SI-24	45	no	no	no	yes	yes	yes	yes	yes

Table 7: Stable grain size assessment and estimated potential of bed scour results for the San Ildefonso Pueblo River Maintenance Priority Site. Results for the 2-yr flow event.

	Current $d_{50}$ (mm)	Current $d_{84}$ (mm)	Est. stable grain size for a 2-yr event	Est. channel elevation stability
SI-18	61	98	36	No incision likely
SI-19	34	68	37	Minor amount of incision possible
SI-20	32	56	41	Minor amount of incision possible
SI-20.4	64	103	48	No incision likely
SI-20.8	50	90	48	No incision likely
SI-21	36	60	49	Minor amount of incision possible
SI-22	43	75	47	Minor amount of incision possible
SI-23	43	69	56	Minor amount of incision possible
SI-24	45	95	56	Minor amount of incision possible



# Priority Site Description and Evolution

Historically, a prominent side channel flowed across the current location of the fishing pond between 1935 and 1956 (Figures 2 & 3). Project photographs from 1956 show that this side channel (Figure 3) had become the prominent channel before a re-alignment project of the Rio Grande occurred in this area. Although the new channel was constructed straight, migrating bends have recently formed upstream from the fishing pond, increasing the bankline sinuosity. The spoil piles upstream from the pond appear to be adding curvature to the main channel by deflecting the thalweg around them. This increased curvature may be enhancing the focus of the river against the east bank and thus enhancing the channel migration process.

## Bank Characteristics

The banks on the east side of the river in this reach are abandoned floodplains with varying heights; four surfaces (terraces) were identified during a field visit in April 2005 (Figures 11 & 12). Terrace surfaces range from about 1 to 7 feet above the normal high water mark. Terrace 1 is the tallest terrace, approximately 7 feet tall is the oldest surface observed in the reach. Pueblo agricultural fields have historically been located on this surface even though the surface was reported to flood at least semi-regularly in the 1930s.

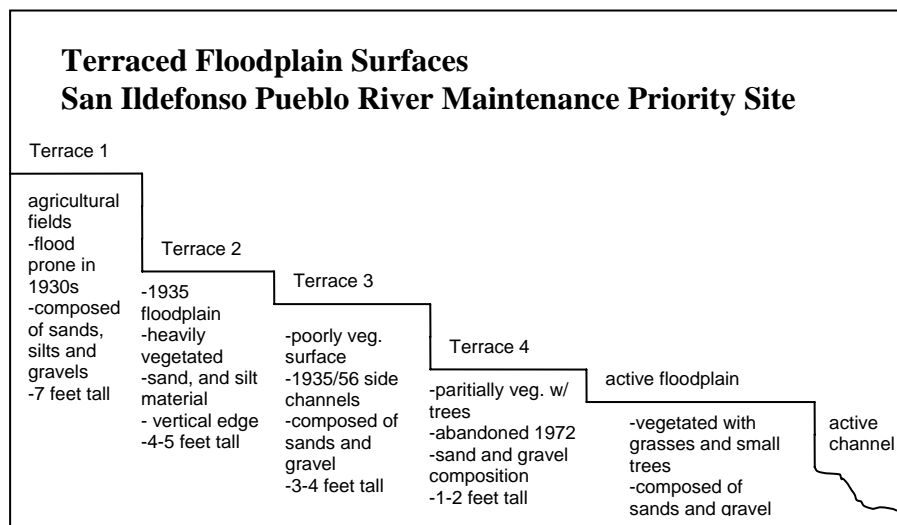


Figure 11: Descriptions of the terraced surfaces at the San Ildefonso Pueblo River Maintenance Priority Site.

Terrace 2 is 4-5 feet tall and appears to have been the riparian floodplain in the 1930s; the migrating bend is eroding this terrace. This surface may have been a partially dissected island prior to 1935 as surface depressions of 1-2 feet were observed on it. The main depression occurs at the east side of the Terrace 2 boundary with Terrace 1; it was likely a historic side channel that separated this terrace from the floodplain. Other depressions/apparent side channels occur throughout the terrace; some of these abandoned side channels feed into the old 1956 main channel near the fishing pond (Terrace 3). Terrace 2 pre-dates 1935 (>70 years) as it was already vegetated at that time; it is composed of

## San Ildefonso Pueblo River Maintenance Priority Site

mostly well packed sand, and silt sediments (Figure 13) and covered with cottonwoods, saltcedar, and other vegetation.

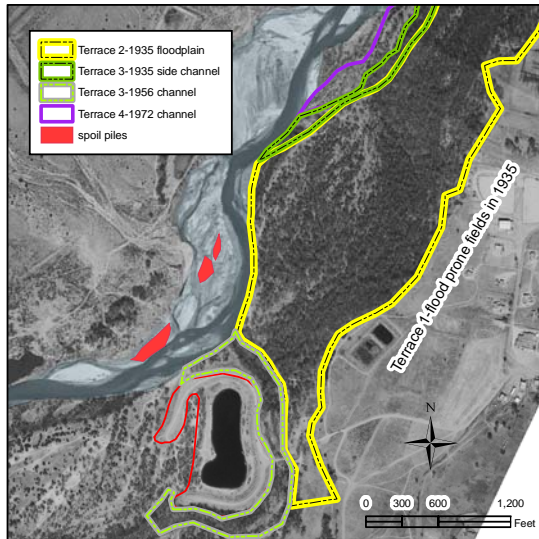


Figure 12: Mapped terrace locations at the San Ildefonso Pueblo River Maintenance Priority Site.



Figure 13: Close-up of the actively eroding Rio Grande bankline at Bend #1 (Terrace #2).

## Bend Migration

The San Ildefonso River Maintenance Priority Site consists of a relatively low curvature bend, approximately 2,000 feet in length, eroding the east bank on the Rio Grande. Continued south-eastward movement of this bend threatens the San Ildefonso fishing pond. Aerial photography used in this assessment includes photos from 1993, 1994, 1996, 1997 and 2001 that were scanned and rectified by J. AuBuchon. Bankline locations were drawn in ArcMap 9.0 by T. Massong. Although 1992 photography exists, the photographs were not available for this assessment; however, bankline locations were digitized from the original 1992 photographs by Jan Oliver (Reclamation: Denver Technical Services Center, GIS and Remote Sensing Group, Denver, Colorado).

### Bend Setup and Evolution

The 1935 data (Figure 2) shows the main 1935 channel flowing predominantly against the western valley wall, with a side channel flowing over the current location of the fishing pond (Figure 2). By 1956, this side channel appears to have become the main Rio Grande channel but was abandoned via a channelization/straightening project (Figure 3). By 1972 (post channelization) alternating bends developed in the river channel, with an apparent eastward moving bend next to the fishing pond. Between 1992 and 1972 the channel bend straightened by eroding the bank upstream from the fishing pond. During this time period the bankline near the fishing pond did not move towards the pond (Figure 2), rather the bend edge appears to have moved slightly away from the pond.

After 1992, a bank-attached bar grew at the downstream end of the bend, effectively splitting the 1992 bend into two smaller bends (Figure 14). The bank-attached bar was partially eroded by 1994, but the bend was still split into the two smaller bends. By 1996, the bar was gone and a larger single bend had formed. This single bend continued to evolve and by the 2001 photos, it had increased its curvature upstream from the pond. Between 1996 and 2001, the upstream half of the bend began to noticeably erode the east river bank. Based on recent field inspections (04/2005), the bend shape has not changed significantly and has continued to erode the east bank.

## San Ildefonso Pueblo River Maintenance Priority Site

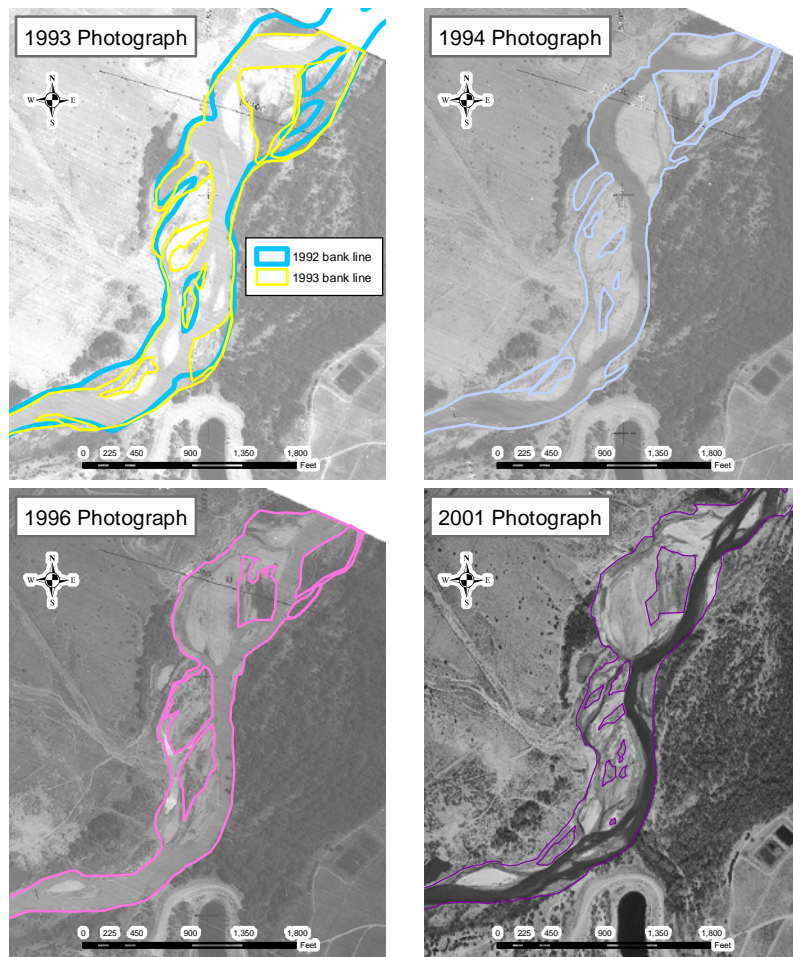


Figure 14: Aerial photos and Rio Grande bank locations for 1993, 1994, 1996 and 2001 for the San Ildefonso Pueblo area.

## Migration Analysis and Rates

The rate of bend migration was estimated using both photography and cross section data. Bench-marked cross section data (Figure 10) are available for several years: 1995, 1996, 1998 and 2005. These data show that the bend has migrated approximately 25 feet in the last ten years between elevations 5506-5508 feet (Figure 15). The average rate of this eastward bank migration is 2.5 ft/yr (Table 8). Unfortunately the actual apex of the bend is upstream from SI-20, and more bank erosion is present at this location; therefore, 2.5 ft/yr should be used as a minimum bank retreat rate for this bend. Based photo data, the maximum bankline retreat is 90 feet since 1993 (~11 ft/yr) with 70 feet since 1996 (14 ft/yr).

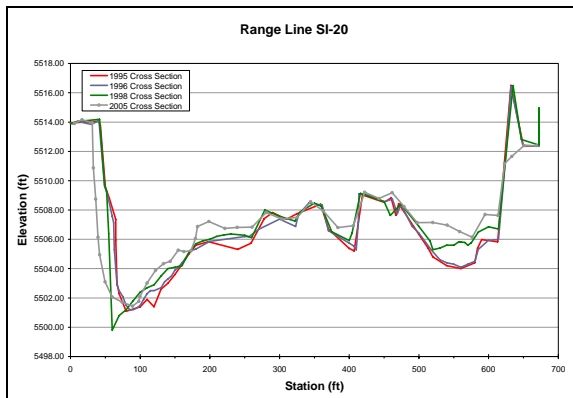


Figure 15: Cross section survey data SI-20 from 1995 through 2005.

Table 8: Bank positions and migration rates for two bends on the Rio Grande at San Ildefonso Pueblo.

<b>East bankline</b>						
Survey Year	1995	1996	1998	2005	Total Movement	Average Rate
Station (ft)	65	66	62	39.6	25.4 ft	2.5 ft/yr
<b>West bankline</b>						
Survey Year	1995	1996	1998	2005	Total Movement	Average Rate
Station (ft)	195	195	235	281	86 ft	9.5 ft/yr

Immediately upstream from the east bank bend is the west bank bend that range line SI-19 intersects. This bend has migrated 86 feet since 1996 (Figure 15 and Table 8). The average rate of this westward bank migration is 9.5 ft/yr (Table 8). The material eroded is recently deposited river sediments that are likely more easily eroded than the terrace sediment on the east bank bend downstream. Although these sediments have not been sampled, field observations are consistent with the cross section data (Figure 15) that shows the sediments form relatively vertical banks and appeared to be composed of silt, sand and gravel.

## Future Bend Evolution

This section of the Rio Grande appears to have a relatively stable channel bed, which indicates that the channel may focus its evolution into lateral erosion/migration as vertical erosion is not a significant process. The eastern bend was not well established until 1996 (Figure 14), when an undulation in the bankline formed. After 1996, the apex location moved predominantly northward with bankline retreat occurring in an eastern direction. In the 2005 runoff period, the bend apex moved rapidly downstream in a southeast direction; the apex migrated approximately 200 feet. Although the apex of this bend initially migrated upstream, a downstream migration direction is expected in the long-term as seen at other



### San Ildefonso Pueblo River Maintenance Priority Site

migrating bends in the watershed (Massong 2005). Based on the current rate of migration and direction, bank erosion is expected to erode through the fishing pond access road in approximately 10 years (Figure 16).

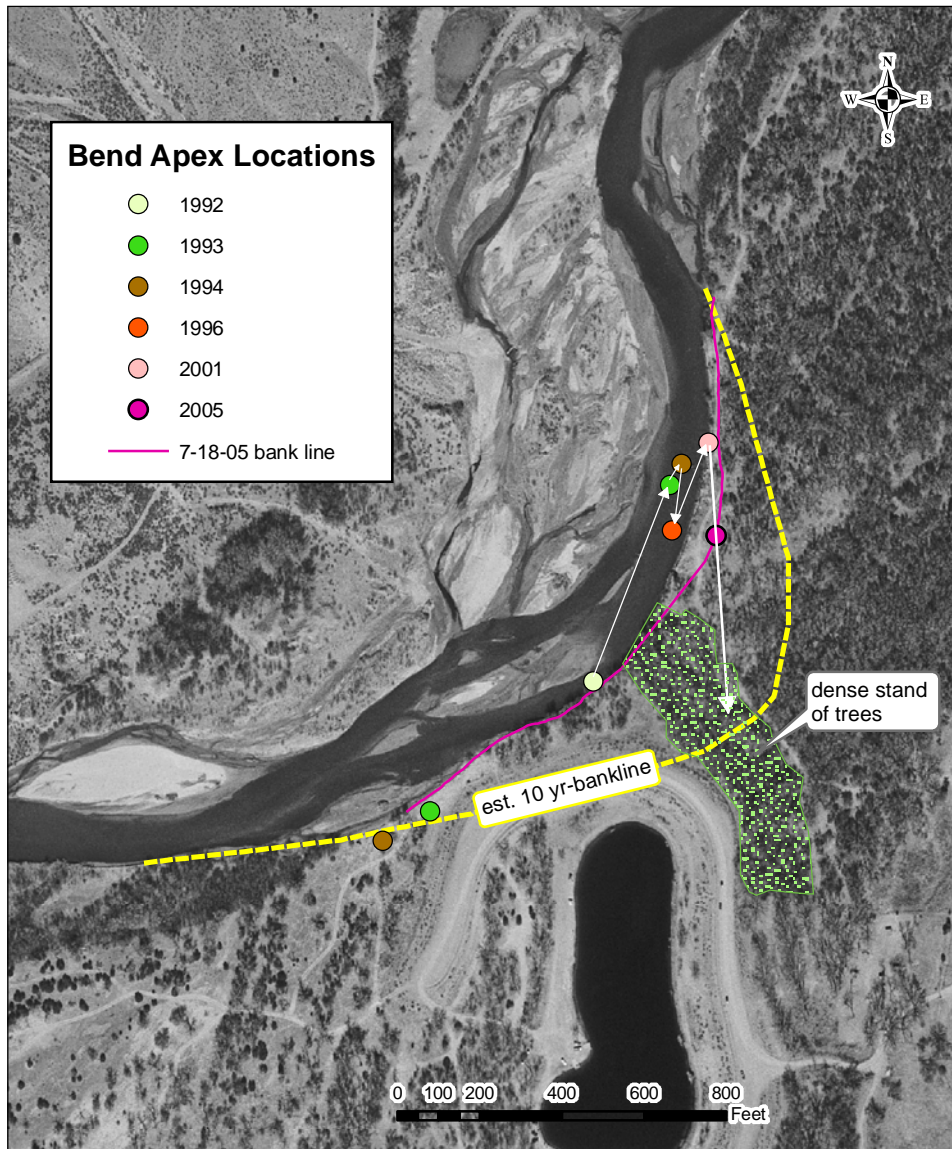


Figure 16: Locations of the bend apex for the Rio Grande bankline at the San Ildefonso Pueblo fishing pond and projected bankline location in 10 years.

## Summary

- In 1935, the channel had very large braids that contained both vegetated and active bars/islands along with extensive floodplain surfaces. After channelization activities in the 1950s, the channel has regained some of the braided planform, but at a much smaller scale with essentially no floodplain.
- Discharge data show that peak flows are significantly smaller after 1942, and that part of the reduced flows appears to be climatic as there was a drought in the 1950s, but that flood control operations on the Rio Chama are likely accounting for the continued reduction in peak flows.
- Suspended sediment data also show variations in concentrations over time, but these variations do not correlate with discharge. Supplies of sediment are likely from local tributaries and upstream in the Rio Grande watershed rather than upstream of Abiquiu Dam on the Rio Chama.
- Current channel characteristics convey the 5-yr return flows without significant overbanking.
- The channel bed is composed of coarse gravel and cobbles; the largest sediment sizes are relatively stable, while the median sizes are mobile near the current 2-yr event.
- Only minor amounts of bed incision are expected in the future.
- Four terraces are present near the fishing pond with the tallest at 7 feet; all of the terraces appear to have been either active channel or floodplains in the 1930s.
- Bend migration appears to have begun in about 1996 with an actively eroding bankline; based on current direction and rate of migration, this bend is expected to jeopardize the fishing pond in approximately 10 years.

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